

Possible Formation of dark-matter galaxies

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Abstract

We attempt to answer whether dark-matter galaxies could be formed in a time span of about 1 *Gyr* or the age of the young Universe. If the dark-matter galaxies would exist in a time span of about 1 *Gyr*, then they might even dictate the formation of the ordinary-matter galaxies. The implications for the structure of our Universe would be tremendous. Thus, the search for dark-matter galaxies should be under way if possible.

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1 Prelude

The phenomenon of clustering, e.g. in our case formation of ordinary-matter galaxies and that of dark-matter galaxies, is a highly nonlinear effect. It is against the tendency toward the uniform distribution or against the democratization. Like the grown-up process, clustering seems to have a life of certain form on its own. This is particularly the case when we talk about the seeded clustering, such as, the aggregation of the matter at the early stage (producing the seeds via strong and electromagnetic forces) followed by the clustering via gravitational force.

It is well-known that the rotation curve of our own spiral galaxy, the Milky Way, is dragged by something invisible that may be four or five times the mass of the Milky Way, if Newton's gravitational law or Einstein's general relativity is assumed to be valid. This is a natural candidate for the clustered dark matter. Dark matter occupies 25% of the current Universe, as oppose to 5% of the visible ordinary matter. And we know that dark matter, owing to their masses, should clusterize even due to gravitational forces, except whether it was soon enough, as compared to one Giga years, the time span that ordinary-matter galaxies form.

Galactic formation, since its start from baryons, nuclei, atoms, molecules, and complex molecules, those from strong forces and electromagnetic forces (and their residual forces), apparently is influenced greatly from something that is not gravitational. We refer this case as the "seeded" clustering. If the "seeded" clustering of this kind were absent, whether galaxies could exist in the time span of the age of the young Universe, say, 10^9 years, is quite questionable.

As said earlier, the spiral arm of our own galaxy, the Milky Way, is influenced by the dark-matter clouds of (4-5) times of the mass of the Milky Way, judging from the unusual

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tail (larger) velocity, or the rotation curve, of the arm. The evidence seems to be reasonably good for other spiral galaxies but of course it would be very interesting if it could be further substantiated.

Thus, what comes to our minds is whether the dark-matter world, 25 % of the current Universe (in comparison, only 5 % in the ordinary matter), would form the dark-matter galaxies, even before the ordinary-matter galaxies. The dark-matter galaxies would then play the hosts of (visible) ordinary-matter galaxies, like our own Milky Way. A dark-matter galaxy is by our definition a galaxy that does not possess any ordinary strong and electromagnetic interactions (with our visible ordinary-matter world). This fundamental question, though difficult to answer experimentally, deserves some thoughts, for the structural formation of our Universe.

In the ordinary-matter world, strong and electromagnetic forces make the clustering a very different story - they manufacture atoms, molecules, complex molecules, and chunks of matter, and then the stars and the galaxies; the so-called "seeded clusterings". The seeds in the dark-matter world could be relatively-stable extra-heavy dark-matter particles - one such particle would be equivalent to thousands of ordinary-matter molecules. Thus, we need to keep in mind the question whether the seeded clustering in the dark-matter world is possible.

But what we have in mind is that, in the ordinary-matter world, the sequence of atoms-molecules-complex molecules-etc. (up to the mass of the TeV level) yields the "seeds" of the clusterings - the seeded clustering that is relevant for the time span of our young Universe. Such seeds for dark-matter galaxies might also come from relatively-stable heavy dark-matter particles (with the mass greater than, e.g., $1 TeV$). Presumably neutrinos (the known one kind of dark matter) alone, with their tiny masses, can in principle aggregate but over the time span much longer than the age of our Universe, $13.7 Gyr$. The ordinary-matter galaxies are manufactured in about the first $1 Gyr$, but clearly with the help of the "seeded" clusterings, as mentioned above.

We start with the minimal Standard Model of particles, which defines, initially, the ordinary-matter world, and describe all kinds of the known interactions - strong, electromagnetic, weak, and other interactions. These particles do aggregate (into atoms, molecules, and then macroscopically gravitational objects) under strong, electromagnetic, and gravitational forces (in a time span of $1 Gyr$, the life of the young Universe) - for weak forces, they are much weaker, too weak for the clustering problem that we are talking about. The assertion that neutrinos and other dark-matter particles are described by some extension of the minimal Standard Model does mean something of critical importance. But we should caution that the extended Standard Model may bring in more in ordinary matter, so long as the new species couple to the ordinary-matter particles such as quarks.

Thus, it is essential to understand the world of the extended Standard Model (for ordinary-matter particles and dark-matter particles) for the question of the large-scale clustering of the dark-matter world. To begin with, we have to ask another very different question on what would be the most likely "extended" Standard Model. So, we need to "analyze" the elements used to write down the minimal Standard Model.

We do know that the world of the minimal Standard Model, the visible ordinary-matter world, seems to be extremely simple. One originally starts out with the electron, a point-like spin-1/2 particle, and ends up with other point-like Dirac particles (such as quarks, other

leptons, and so on), but with interactions through gauge fields modulated by the Higgs fields. This is what we experimentally know, and it is a little strange that it seems to be "complete" and that nothing else seems to exist (until the dark-matter world "calls for" the "extended" Standard Model). Note that all particles in the minimal Standard Model are "point-like" since under the best resolution of 10^{-18} cm they don't seem to have a size. After Dirac's equation we have in fact searched for the point-like particles, now for over eighty years. It seems that Dirac equations explain all the relativistic point-like particles and their interactions. So, why don't we formulate a working rule to describe this fact? Let's call it as "the Dirac Similarity Principle".

The other striking experimental fact of the minimal Standard Model is that, for the past forty years, we have been looking for the Higgs particle(s) - the spin-0 scalar particle(s), but failed to find any positive signature for it (them). I try to formulate this fact as "the minimum Higgs hypothesis". Here we don't mean "the non-existence of Higgs" but rather we mean that if they exist then they should be minimal. In our opinion, mass generation in our "basic" theory is so important that this Higgs question has to be answered one way or the other.

In other words, it would be too broad to identify which extended Standard Model could be the choice. With the "minimum Higgs hypothesis", the Higgs sector is essentially fixed once the group $SU_c(3) \times SU_L(2) \times U(1) \times G$ with G the extension is fixed. On the other hand, the "Dirac Similarity Principle" helps to fix the particle contents. With these working rules [1] that are in essence used for several decades, the search for the correct extended Standard Model could be sharpened and thus much easier.

2 Dirac Similarity Principle and Minimum Higgs Hypothesis

In the minimal Standard Model that has been experimentally verified and that describes the ordinary-matter world, it could be understood as a world consisting of a set of point-like Dirac particles interacting through gauge fields modulated by the Higgs fields. The only unknowns are neutrinos, which we believe may also be point-like Dirac particles. Thus, the minimal Standard Model is basically a Dirac world interacting among themselves through gauge fields modulated by the Higgs fields. In extending the minimal Standard Model, we try to keep the "principle" of point-like Dirac particles intact - thinking of the eighty-year experience some sort of sacred. On the other hand, the forty-year search for Higgs (scalar fields) still in vain amounts to "minimal Higgs hypothesis". These two working hypotheses simplify a lot of things. In fact, the situation from something un-manageable without the working rules becomes manageable, if the two rules are adopted. Of course, we have to worry about what if one of the two working rules doesn't hold, but it doesn't hurt to begin in this particular way.

That is, we follow another paper [1] and introduce "the Dirac similarity principle" that every "point-like" particle of spin-1/2 could be observed in our space-time if it is "connected" with the electron, the original spin-1/2 particle. For some reason, this clearly has something to do with how relativity and the space-time structure gets married with spin-1/2 particles. This is interesting since there are other ways to express spin-1/2 particles, but so far they are not seen perhaps because they are not connected with the electron. In other words, the partition between geometry (in numbers such as $4 \times 4 \sigma/2$ in the angular momentum) and

space-time (such as $\vec{r} \times \vec{p}$) is similar to the electron. We adopt "Dirac similarity principle" as the working "principle" as we extend the Standard Model to include the dark-matter particles as well.

These are "point-like" Dirac particles of which the size we believe is less than 10^{-18} cm , the current best resolution of the length. Mathematically, the "point-like" Dirac particles are described by "quantized Dirac fields" - maybe via a renormalizable lagrangian. The "quantized Dirac fields", which we can axiomatize for its meaning, in fact does not contain anything characterizing the size (maybe as it should be). On other hand, the word "renormalizability" might contain something describing the change of the sizes.

Now that the dark matter are the species of the extended Standard Model; then the dark matter world might exhibit the clustering effect, just like the ordinary matter world. To make a lengthy story short, I would suggest the final extended Standard Model to be based on the group $SU_c(3) \times SU_L(2) \times U(1) \times SU_f(3) \times SU_R(2)$. Why? Let's explain.

Why? We know that there are three generations of quarks and leptons but don't know why. This is clearly a symmetry that we have already "seen", but not in details. In view of the existing structure of the minimal Standard Model, we suspect that most symmetries may be realized in the form of gauge theories, in this case a family gauge theory [2]. [We think very hard that, what symmetry the family symmetry would be, if it is not a gauge theory.] Of course, we could choose to do nothing about it. On other hand, the missing right-handed sector is always a troublesome for the symmetry people (like me). So, the next option is to employ the notion originated by Pati and Salam [3] that the left-right symmetry is restored at some even higher energy. What we try to restore is for the dark-matter world. Maybe it is rather difficult to verify it experimentally but we want to set the tone at least.

Let's "apply", via step by step, the Dirac similarity principle and the minimum Higgs hypothesis to our problem. The neutrinos are now Dirac particles of some kind - so, right-handed neutrinos exist and the masses could be written in terms of them. To make Dirac neutrinos massive, we need a Higgs doublet for that. Is this Higgs doublet a new Higgs doublet? In principle, we could use the Standard-Model Higgs doublet and take and use the complex conjugate (like in the case of quark masses) - the problem is the tininess of these masses and if this would go it is definitely un-natural. (Note that during the old days when neutrinos are suspected to be massless, there might be strong reasons to suspect that neutrinos might not be Dirac particles.)

Let's begin with the $SU_c(3) \times SU_L(2) \times U(1) \times U(1)$ case - the extra Z'^0 extension [4]. In all cases (not just the extra Z'^0 case), if a new and "remote" Higgs doublet would exist and the tininess of the neutrino masses is explained by the neutrino couplings to the "remote" Higgs, then it comes back to be "natural". Why are the neutrino couplings to "remote" Higgs doublet should be small? - just similar to the CKM matrix elements (that is, the 31 matrix element is much small than the 21 matrix element); the other "naturalness" reason.

In the extra Z'^0 case, we are forced to add some Higgs (since the standard Higgs doublet is already used up). Another "remote" Higgs doublet would be the natural choice, coming back to the $2+2$ option [4]. Note that the couplings to the "remote" Higgs would be much smaller than to the ordinary one. As said earlier, this hypothesis makes the case of the tiny neutrino masses very natural and, vice versa, we could say that we rephrase the natural situation to get the hypothesis. Why do we adopt the "minimum Higgs hypothesis" - just one and only one "remote" Higgs doublet? For more than forty years, we haven't found

any solid signature for the Higgs; that the neutrinos have tiny masses (by comparison with quarks and charged leptons) is another reason. So, if there is only one extra Z'^0 , then there is only one "remote" Higgs doublet.

That neutrinos have tiny masses can be taken as a signature that there is a heavy extra Z'^0 , so that a new Higgs doublet should exist. This extra Z'^0 then requires the new "remote" Higgs doublet[4]. This Higgs doublet also generates the tiny neutrino masses. This is one possibility, $SU_c(3) \times SU_L(2) \times U(1) \times U(1)$; with minimum Higgs hypothesis, we are talking about the unique extra $U(1)$ generation.

In fact, the extra Z'^0 alone would force us to accept the remote Higgs doublet; after the Higgs mechanism (i.e. the mass-generation mechanism) there are three Higgs particles left (i.e. one neutral and one complex) - one unpleasant consequence. Thus, in view of the "minimum Higgs hypothesis", the $SU_c(3) \times SU_L(2) \times U(1) \times U(1)$ case could be "ruled out".

Or, we could require that the right-hand $SU_R(2)$ gauge fields exist to restore the left-right symmetry[3]. In this case, the left-handed sector and the right-handed sector each has the Higgs doublet, each is the left-right image of the other. The original picture[3] contains many options regarding the Higgs sector, but now the "minimum Higgs hypothesis" makes the unique choice. In our terms, the right-handed Higgs would be the "remote" Higgs for the left-handed species. That determines the size of the coupling, including the tiny neutrino masses. Note that the only cut-off is the huge masses of the right-handed gauge bosons (by keeping the left-right symmetry). We believe that the phenomenology of the said unique left-right symmetric model should be seriously pursued.

In this case, the right-handed Higgs doublet is almost eaten by the right-handed gauge bosons, except one neutral Higgs particle. The "minimum Higgs hypothesis" is thus very well satisfied. That would be another reason why we could take the case seriously.

There is an interesting option - the family gauge theory [2]. Note that the right-handed neutrinos do not appear in the minimal Standard Model. So, we could make a massive $SU_f(3)$ gauge theory completely independent of the minimal Standard Model, including the particle content. For example, we could treat $(\nu_{\tau R}, \nu_{\mu R}, \nu_{e R})$ as a triplet under this $SU_f(3)$ - so to give rise to a family gauge theory. Because the anomaly does not hurt, we could drop the right-handed labels from the neutrinos. This completes the derivation of the family gauge theory [2].

Here we are curious at why there are three generations - is the family symmetry in fact some sort of gauge symmetry because that the associated interactions are too weak? We try to combine the minimal Standard Model $SU_c(3) \times SU_L(2) \times U(1)$ with $SU_f(3)$, with $(\nu_{\tau R}, \nu_{\mu R}, \nu_{e R})$ the basic $SU_f(3)$ triplet. Here $SU_f(3)$ has an orthogonal neutrino multiplet since the right-handed neutrinos do not enter at all the minimal Standard Model. In this way, we obtain the $SU_c(3) \times SU_L(2) \times U(1) \times SU_f(3)$ minimal model. Or, the right-handed indices could be removed altogether in the family group, just like the other $SU_c(3)$ combining with $SU_L(2) \times U(1)$ as far as anomalies are concerned. Again, Dirac similarity principle and minimum Higgs hypothesis saves the day - uniqueness in the choice.

In this case [2], the three family calls for $SU_f(3)$ and to make the gauge bosons all massive the minimum choice would be a pair of Higgs triplets - apparently a kind of broken gauge symmetry. The scenario is such that the eight gauge bosons and the four left-over Higgs particles all have masses greater than a few TeV 's. Under the "minimum Higgs hypothesis", the structure of the underlying Higgs mechanism is pretty much determined.

Then, neutrinos acquire their masses, to the leading order, with the aid of both the Higgs triplets. In addition, the loop diagrams involving the gauge bosons also contribute to neutrino masses.

Maybe we could move one step forward. We see that the three generations are already there (even though we have not seen the feeble interactions so far). Judging from the energies which we could reach at LHC, we could set the mass scale at a few $TeV's$. On the other hand, until the LHC energies we haven't seen any signature that the right-handed sector would be back - so setting the scale to at least hundreds of $TeV's$. So, we are talking about the extended Standard Model based on the group $SU_c(3) \times SU_L(2) \times U(1) \times SU_f(3) \times SU_R(2)$.

To push forward the "final" Standard Model, we should have a comprehensive successful phenomenology. On the $SU_c(3) \times SU_L(2) \times U(1) \times SU_f(3) \times SU_R(2)$ Standard Model, the first goal is to pin down the manifestations of the $SU_f(3)$ gauge sector. The physics of the neutrino sector gets modified and the $\tau - \mu - e$ universality is no longer there, depending on the strength of the $SU_f(3)$ coupling. The reason for the neutrino couplings is that the neutrino is only species in the ordinary matter that acts also as dark matter. And if the $SU_f(3)$ gauge sector is there, its communication with us (the ordinary matter) is only through the neutrinos. So, the breakdown of the $\tau - \mu - e$ universality, albeit it could be small, is absolutely crucial.

Qualitatively, dark-matter particles refers to those particles which do not participate the ordinary strong and electromagnetic interactions. It is a natural but stringent definition of "the dark matter". For the extended Standard Model $SU_c(3) \times SU_L(2) \times U(1) \times SU_f(3) \times SU_R(2)$ mentioned above, the right-handed gauge bosons do not belong to the dark-matter world since they couple to quarks for instance and so to ordinary strong interactions. The right-handed gauge bosons, once produced, would decay into quarks and leptons immediately. So, under this definition of dark matter, we introduce the likely group but not the new species of dark matter. On the other hand, all the particle species in the $SU_f(3)$ sector, as they do not participate directly the ordinary strong and electromagnetic interactions, can be classified as "dark matter". That is, the extensions of the minimal Standard Model bring in new ordinary-matter particles and occasionally some dark-matter particles. If we look at the missing right-handed sector or at the above specific extra Z'^0 model, we are working only with ordinary-matter particles, with the only exception of neutrinos. (Of course, with a new group and with some artificial adjustments, we could "manufacture" some new species of dark matter, but it will be at variance with the minimum Higgs hypothesis or with the Dirac similarity principle.)

This implies that the family gauge theory is so far the only way to get the new species of dark matter, besides the neutrinos. The additional $U(1)$ or $SU_R(2)$ gauge sector couples to the quark sector by construction and so could not be the dark-matter species. Furthermore, the role of the neutrinos in the $SU_f(3)$ gauge theory means that neutrinos serve as the bridge between the ordinary-matter world and the dark-matter world. Otherwise, we can't think of the connections between the dark-matter and ordinary-matter worlds and those spiral galaxies (such as our Milky Way) are truly unthinkable. Some dark-matter particles that can serve as the bridge are needed if the current thinking about the spiral galaxies can be accepted.

3 Some Discussions

In the Standard Model of particle physics, we introduce the Higgs sector as the most efficient way to explain why these particles have masses (i.e. the so-called "mass generation"). The physics of mass generation should be among the most important piece for our knowledge toward physics. Whether or not the Higgs sector should be used in this context may be subject to discussions, But the picture is the most simple - so, we should explore this scenario first.

Thus, let us return to, for instance, the extra Z'^0 model to illustrate the "minimum Higgs hypothesis". There are left-handed neutrinos belong to $SU_L(2)$ doublets while the right-handed neutrinos are singlets. The term specified by

$$\varepsilon \cdot (\bar{\nu}_L, \bar{e}_L) \nu_R \varphi \quad (1)$$

with $\varphi = (\varphi^0, \varphi^-)$ the new "remote" Higgs doublet could generate the tiny mass for the neutrino and it is needed for the extra Z'^0 .

We need to introduce one working hypothesis on the couplings to the Higgs - to the first (standard) Higgs doublet, from the electron to the top quark we call it "normal" and G_i is the coupling to the first Higgs doublet, and to the second (extra, "remote") Higgs doublet the strength of the couplings for the Dirac particles is down by the factor $(v/v')^2$ with v the VEV for the standard Higgs and v' the VEV for the (remote) Higgs. Presumably, this contains in the "minimum Higgs hypothesis". The hypothesis sounds very reasonable, similar to the CKM matrix elements, and one may argue about the second power but for the second Higgs fields some sort of scaling may apply.

With the working hypothesis, the coupling of the neutrinos to the standard Higgs would vanish completely (i.e., it is natural) and its coupling to the second (remote) Higgs would be $G_j(v/v')^2$ with G_j the "normal" size.

The "minimum Higgs hypothesis" amounts to the assertion that there should be as less Higgs fields as possible and the couplings would be ordering like the above equation, Eq. (1).

Indeed, in the real world, neutrino masses are tiny with the heaviest in the order of 0.1 eV . The electron, the lightest Dirac particle except neutrinos, is 0.511 MeV [5] or $5.11 \times 10^5 \text{ eV}$. That is why the standard-model Higgs, which "explains" the masses of all other Dirac particles, is likely not responsible for the tiny masses of the neutrinos. The "minimum Higgs hypothesis" makes the hierarchy very natural.

In an early paper in 1987[4], we studied the extra Z'^0 extension paying specific attention to the Higgs sector - since in the Minimal Standard model the standard Higgs doublet Φ has been used up by (W^\pm, Z^0) . We worked out by adding one Higgs singlet (in the so-called 2+1 Higgs scenario) or adding a Higgs doublet (the 2+2 Higgs scenario). It is the latter that we could add the neutrino mass term naturally. (See Ref.[4] for details. Note that the complex conjugate of the second "remote" Higgs doublet there is just the φ above.) In other words, we can select the 2+2 Higgs scenario making use of the "minimum Higgs hypothesis".

The new Higgs potential follows the standard Higgs potential, except that the parameters are chosen such that the masses of the new Higgs are much bigger. The coupling between the two Higgs doublets should not be too big to upset the nice fitting[5] of the data

to the Standard Model. All these go with the smallness of the neutrino masses. Note that spontaneous symmetry breaking happens such that the three components of the standard Higgs get absorbed as the longitudinal components of the standard W^\pm and Z^0 .

As a parenthetical note, we could remark on the cancelation of the flavor-changing scalar neutral quark currents. Suppose that we work with two generations of quarks, and it is trivial to generalize to the physical case of three. We should write

$$\begin{aligned}
&(\bar{u}_L, \bar{d}_L') d_R' \Phi + c.c.; \\
&(\bar{c}_L, \bar{s}_L') s_R' \Phi + c.c.; \\
&(\bar{u}_L, \bar{d}_L') u_R \Phi^* + c.c.; \\
&(\bar{c}_L, \bar{s}_L') c_R \Phi^* + c.c.,
\end{aligned} \tag{2}$$

noting that we use the rotated right-handed down quarks and we also use the complex conjugate of the standard Higgs doublet. This is a way to ensure that the GIM mechanism[6] is complete. Without anything to do the opposite, it is reasonable to continue to assume the GIM mechanism.

There are additional questions such as: How about the couplings between quarks (or charged leptons) and the (non-standard) remote Higgs? "Minimum Higgs hypothesis" helps to set these couplings to zero or to be very small. Note that the remote Higgs was introduced to give mass(es) to the new gauge boson(s). For the new gauge bosons (such as the right-handed W^\pm , Z^0), their large masses serve as the cut-off. For the family gauge theory, on the other hand, all the couplings between family gauge bosons and all Dirac particles, except neutrinos, vanish identically. The mass-generation mechanism involves both the fermion masses and the gauge-boson masses - a complicated game. When there are standard and remote Higgs, we need something like "minimum Higgs hypothesis" to determine which Higgs gives rise to a given mass (of a fermion or gauge boson) or both Higgs do the job cooperatively.

As said earlier, we would "rule out" the extra Z'^0 model for three physical Higgs particles, seemingly as against "the minimum Higgs hypothesis". If there is an extra Z , then what is the situation for W^\pm and the restoring left-right symmetry would be in order. Thus, the global view of "the minimum Higgs hypothesis" might be there in ruling out the extra Z^0 model or others (that have too many physical Higgs particles), for the reason that there remain too many Higgs particles after spontaneous symmetry breaking (SSB).

There are two additional related remarks about the Higgs structure. The first remark related to the $SU_L(2) \times SU_R(2) \times U(1)$ model [3]. The second one is related to the family (gauge) symmetry [2].

In the $SU_L(2) \times SU_R(2) \times U(1)$ model[3], we assume that in the left and right parts each has one Higgs doublet (minimal) and that we could try to make the tiny neutrino masses in the right-handed sector - viewed as the "remote" Higgs for neutrinos in the entire construction. This appears to be rather natural. After SSB, there remain only two neutral Higgs. Thus, we should think more about the left-right symmetric model very seriously - except that we should think of the Higgs mechanism in a real minimum fashion. This means that, owing to the "minimum Higgs hypothesis", we are advocating a particular kind of the left-right symmetric model.

Regarding the family (gauge) symmetry, it is difficult to think of the underlying reasons

why there are three generations (of quarks and leptons). But why? This is Raby's question; should we stop asking if the same question went by without an answer for decades? This is some symmetry that we already see, except we don't know why. This is why we promote the family symmetry to the family gauge symmetry[2]. In both cases (left-right and family), we could keep the validity of the proposed Dirac similarity principle and the "minimum Higgs hypothesis" - an interesting and strange aspect.

In the family gauge theory, we have to introduce a pair of complex Higgs triplets in order to guarantee that all gauge bosons ("familon") and the remaining four Higgs particles are massive, say, greater than a few TeV . They have to be massive mainly because, if massless, the loop diagrams involving these dark-matter particles could become dominant. We might replace a pair of complex Higgs triplets by three real triplets but that would deviate the standard practise in using Higgs. Further, the pair of complex Higgs triplets and the neutrino triplet can form a singlet, the (off-diagonal) neutrino mass term. This, together with the familon loop diagrams, gives plenty of room for fitting the neutrino masses.

4 The time span of 1 Gyr – the age of our young Universe

Suppose that the spiral of the Milky Way is caused by the dark-matter aggregate of four or five times the mass of the Milky Way, and similarly for other spiral galaxies. This aspect will serve as a "basic fact" for our analysis of this section.

Let's look at our ordinary-matter world. Those quarks can aggregate in no time, to hadrons, including nuclei, and the electrons serve to neutralize the charges also in no time. Then atoms, molecules, complex molecules, and so on. These serve as the seeds for the clusters, and then stars, and then galaxies, maybe in a time span of 1 Gyr . The aggregation caused by strong and electromagnetic forces is fast enough to give rise to galaxies in a time span of 1 Gyr . On the other hand, the weak interactions proceed fairly slowly in this time span and they could not contribute in the time span of 1 Gyr . The said aggregation in the ordinary-matter world gave rise to the "seeded" clustering, so much faster than if there would be no "seeded" clustering (presumably, many order of magnitude away).

On the other hand, the seeded clusterings might proceed with abundance of extra-heavy dark-matter particles such as familons and family Higgs, all greater than a few TeV and with relatively long lifetimes. They belong to the dark-matter world, so they don't interact via strong or electromagnetic interactions (not directly, but indirectly through loops).

The first part of our assertion states that the ordinary-matter world and the dark-matter world should be jointly described by the extended Standard Model, renormalizable and obeying "Dirac similarity principle" and the "minimum Higgs hypothesis". In other words, one, the last, "extended Standard Model" should exist, to complete the saga of the "Standard Model" for our space-time. Our Universe is after all consistent. We propose the extended Standard Model based on $SU_c(3) \times SU_L(2) \times U(1) \times SU_f(3) \times SU_R(2)$.

The statement that all ordinary-matter particles and dark-matter particles are described by the extended Standard Model is important, but maybe not sufficient for the clustering, and in particular for the "seeded" clustering in a time span of, say, 1 Gyr , the age of our young Universe. The missing part is this: unless the "seeded" clustering in the dark-matter world, the story of our young Universe (in a time span of 1 Gyr) could not happen and the relatively-fast spiral arm of our Milky Way had to come from somewhere else.

5 Are there dark-matter galaxies?

In this note, we investigate the "seeded" clustering of dark matter particles, including neutrinos, by proposing to use the "extended" Standard Model to describe dark matter particles. We extend the minimal Standard Model using Dirac Similarity Principle and minimum Higgs hypothesis - the experience of a half or a century.

Using the extended Standard Model, we proceeded to look into the "seeded" clusterings, which may be relevant in a time span of about 1 Gyr , the life of the young Universe. The seeds might be the heavy dark-matter particles such as familons or family Higgs. In that case, dark-matter galaxies might be formed before ordinary-matter galaxies.

If the dark-matter galaxies exist and play the hosts to the ordinary-matter galaxies, the dark-matter hosts get formed at first. The picture of our Universe is completely different from the conventional thinking, but it makes more sense in terms of the 25% dark matter versus the 5% visible ordinary matter. Apparently, the dark-matter galaxies, judging from the tiny neutrino masses and the feeble interactions, would be much bigger, maybe by a couple of orders (in length), than the visible ordinary-matter galaxies to which they host. Our own spiral galaxy, the Milky Way, serves as the best example.

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